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More Efficient Live-Fire Rifle Marksmanship Evaluation

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U.S. Army Research Institute

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14. ABSTRACT *(Maximum 200 words)*: To examine the feasibility of enhancing live-fire rifle marksmanship evaluation efficiency on the U.S. Army's 40-round standard qualification course, 2 groups of 90 One-Station-Unit Infantry trainees fired 20 rounds from the (foxhole) supported position followed by 20 rounds from the (prone) unsupported position. A significant ($p \leq .05$) positive linear relation between the total number of targets hit and the number of hits fired under each position was found for the formative group (Group 1) and confirmed for the cross-validation group (Group 2), with the former group's predictive models accounting for about two thirds of the variance in the total hit scores of both groups. Separate look-up-table tools were then developed from pooled group data for predicting first-attempt qualification at the Marksman, Sharpshooter, and Expert levels on the basis of either supported or unsupported position hit scores. Thus, rifle marksmanship proficiency, heretofore measured on the basis of 40 rounds, can be accurately predicted on the basis of only 20 rounds fired from either fighting position, although use of scores fired from the supported position is recommended until further research can be conducted. These tools can serve as easy-to-use diagnostic instruments for (a) identifying who should continue with qualification firing (e.g., those likely to qualify after firing 20 rounds) and who should not (e.g., those unlikely to qualify after firing 20 rounds), and (b) providing empirically derived performance standards needed in the future to assess rifle marksmanship proficiency during practice, as well as qualification, on the basis of 20 rather than 40 rounds, thereby saving both range time and ammunition without sacrificing evaluative integrity.

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MORE EFFICIENT LIVE-FIRE RIFLE MARKSMANSHIP EVALUATION

EXECUTIVE SUMMARY

Research Requirement:

Examine feasibility of enhanced live-fire rifle marksmanship evaluation efficiency on the U.S. Army's standard qualification course.

Procedure:

Two groups of 90 One-Station-Unit (OSUT) Infantry trainees fired 20 rounds from the (foxhole) supported position (Table 1) followed by 20 rounds from the (prone) unsupported position (Table 2) in fulfillment of Basic Rifle Marksmanship (BRM) qualification course requirements at Fort Benning, GA. To identify, and assess the validity of, the relation between Table 1 and total target hits, and between Table 2 and total hits, a split-group, cross-validation design was used whereby Group 1 was used to develop a prediction equation between Table 1 and total hits. This equation was then applied to Group 2 to determine if total hit scores could be successfully predicted. An analogous approach was used for predicting total hits from Table 2 hits fired by Group 1 and then applied to Group 2. All statistical analyses were based on the number of hits fired on the shooters' first qualification attempt and a rejection region of .05.

Findings:

The findings indicate that (a) a positive linear relation exists between total table hit scores and those fired from either the Table 1 supported or Table 2 unsupported position, and (b) these relations are both consistent and of sufficient magnitude to support development of practicable tools, in the form of look-up tables, for predicting the probability of first-attempt success on the Army's standard qualification course at the Marksman, Sharpshooter, and Expert levels. Thus, rifle marksmanship proficiency, heretofore measured on the basis of 40 rounds, can be accurately predicted, and therefore evaluated, on the basis of only 20 rounds fired from either the supported or unsupported position, although the former position is recommended until additional research can be conducted.

Utilization and Dissemination of Findings:

These tools can serve as easy-to-use diagnostic instruments for (a) identifying who should continue with qualification firing (i.e., those likely to qualify after firing 20 rounds) and who should not (i.e., those unlikely to qualify after firing 20 rounds), and (b) providing empirically derived performance standards needed in the future to assess rifle marksmanship proficiency on the basis of 20 rather than 40 rounds, thereby saving both range time and ammunition while maintaining evaluative integrity. The U.S. Army Reserve Command's Weapons Training Program Manager sponsored this research and has been presented with its findings.

MORE EFFICIENT LIVE-FIRE RIFLE MARKSMANSHIP EVALUATION

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More Efficient Live-Fire Rifle Marksmanship Evaluation

Introduction

Because of budgetary concerns over the cost of ammunition, equipment, and live-fire range facilities, the Army is always searching for more efficient ways to train and evaluate weapons proficiency. This search has often led to reliance on some sort of simulation-based exercise or device. The Conduct-of-Fire Trainer (COFT) (Headquarters, Department of the Army, 2000), for example, has been successfully used for years to train and evaluate tank crew gunnery because the alternative of using real tanks, live ammunition, and outdoor ranges simply takes too long and costs too much. COFT-based evaluation, in contrast, can often be accomplished in garrison without ever firing a live round down range (Hagman & Smith, 1996).

Simulation has also been successfully used to train and evaluate rifle marksmanship (e.g., Schendel, Heller, Finley, & Hawley, 1985). Recently, for instance, the Laser Marksmanship Training System (LMTS) has incorporated the use of barrel-appended, trigger-activated, eye-safe lasers and light-sensitive, scaled targetry within a computer-managed environment to give shooters (a) the benefit of training with their own weapons without the need for live ammunition (Dunlin, 1999; Hagman, 2000), and (b) the opportunity to fulfill yearly qualification requirements without going to the range (Smith & Hagman, 2000).

Reliance on simulation to augment live fire, or to substitute for it, is just one way, however, to promote efficient evaluation of weapons proficiency. Another, perhaps equal or more efficient, way is to streamline the live-fire evaluation process itself. Gunnery proficiency on Tank Table VIII (Headquarters, Department of the Army, 2001), for instance, can be successfully evaluated by predicting crew chances of first-attempt qualification after each engagement is fired rather than by typically waiting until the firing of all ten (Smith & Hagman, 1998). Under this approach, successful first-attempt qualification can be accurately predicted for most tank crews after the firing of as few as two engagements, thereby saving valuable range time and ammunition for other purposes (e.g., platoon-level exercises) without sacrificing evaluative integrity (Hagman, 2001; Hagman & Smith, 1999). The present research examined the feasibility of extending this approach to the evaluation of rifle marksmanship proficiency by using only half the number of rounds typically fired during record fire qualification and practice leading up to it.

Method

Participants

First-attempt target hit scores were taken from the range computer score sheet printouts of 180 Infantry trainees who fired for record on the standard qualification course at Fort Benning, GA, in fulfillment of the Basic Rifle Marksmanship (BRM) proficiency evaluation requirements of One-Station Unit Training (OSUT).

Procedure

Military range personnel conducted M16A2 rifle qualification firing in accordance with procedures described in Field Manual (FM) 3-22.9 (Headquarters, Department of the Army, 2003). Shooters received 40 rounds of 5.56mm ammunition with which to engage 40 timed, E- and F-type silhouette targets, that popped up individually or in pairs at ranges of from 50-300m, over the course of firing two tables of 20 targets each. Table 1 was fired from the (foxhole) supported fighting position, whereas Table 2 was fired from the (prone) unsupported fighting position. The number of targets hit was first recorded for each table and then combined to arrive at a total score from which shooter qualification status was determined. Hit numbers corresponding to specific proficiency classifications were as follows: 0-22, Unqualified; 23-29, Marksman; 30-35, Sharpshooter; 36-40, Expert. All scores were verified by the noncommissioned officer in charge of the range before being entered for record.

Design

To identify, and assess the validity of, the relation between Table 1 and total hits, and between Table 2 and total hits, a split-group, cross-validation design (Hagman, 1998; Tatsouka, 1969) was used whereby the initial sample of 180 shooters was divided randomly into two groups of 90 shooters each. Group 1 was used to develop a prediction equation between Table 1 and total hits. This equation was then applied to Group 2 to determine if total hit scores could be successfully predicted. An analogous approach was used for predicting total hits from Table 2 hits fired by Group 1 and then applied to Group 2. All statistical analyses were based on the number of hits obtained on the shooters' first qualification attempt and a rejection region set at .05.

Results and Discussion

Table 1

Group 1. Table 1 hit scores ranged from 4 to 19 ($M = 12.56$, $SD = 3.17$) and total hit scores ranged from 4 to 37 ($M = 26.80$, $SD = 5.64$). Using the Statistical Package for the Social Sciences (SPSS) for Windows Version 11.5.1 (2002), a least-squares, regression-based prediction equation of the form $Y' = B_0 + B_1(X_1)$ was developed in which Y' was the predicted total hit score (criterion), B_0 was the intercept/constant (or theoretical criterion score when the predictor variable equals zero), B_1 was the empirically derived regression coefficient linking changes in the criterion variable (total hit score) with changes in the predictor variable (Table 1 hit score), and X_1 was the obtained Table 1 hit score.

A significant linear relation, $Y' = 8.76 + 1.45(X_1)$, $SE = 3.34$ was found between Table 1 and total table performance, $F(1, 88) = 165.84$. In addition, the Pearson Product-Moment correlation ($r = .81$) between predicted and actual total hit scores was significant, with the former accounting for almost two thirds of the variance in the latter ($r^2 = .653$, adjusted $r^2 = .649$). Thus, Group 1 scores fired on Table 1 from the supported firing position were both linearly related to, and reasonably good predictors of, total hit scores fired from both the supported and unsupported firing positions.

Group 2. Table 1 hit scores ranged from 3 to 20 ($M = 12.71$, $SD = 3.67$) and total hit scores ranged from 9 to 37 ($M = 26.63$, $SD = 5.86$). Following cross-validation procedures described by Tatsuoka (1969), the Group 1 regression equation was used to predict Group 2 total hit scores, and then the relative amount of variance accounted for in each group was compared. A significant linear relation, $Y' = 1.15 + .94(X_1[predicted])$, $SE = 3.12$, was found between actual and predicted (from Group 1) total hit scores for Group 2, $F(1, 88) = 225.50$. The resulting correlation ($r = .85$) was significant, and the associated Group 2 r^2 of .719 (adjusted $r^2 = .716$) did not differ significantly from the r^2 of .653 (adjusted $r^2 = .649$) found for Group 1 ($z = .81$), indicating that the Group 1 prediction equation accounted for a comparable amount of total hit score variance in the two groups. Thus, the Group 1-based predictive model was found to be valid and, therefore, likely to maintain similar efficiency when used to predict the total hit scores of other shooter samples.

Table 2

Group 1. Table 2 hit scores ranged from 0 to 20 ($M = 14.24$, $SD = 3.60$) and total hit scores ranged from 4 to 37 ($M = 26.80$, $SD = 5.64$). A significant linear relation, $Y' = 7.72 + 1.34(X_1)$, $SE = 2.94$ was found between Table 2 and total table performance, $F(1, 88) = 238.62$. The correlation ($r = .86$) between predicted and actual total hit scores was also significant, with the former accounting for nearly three quarters of the variance in the latter ($r^2 = .731$, adjusted $r^2 = .728$). Thus, Group 1 scores fired from the unsupported firing position were both linearly related to, and reasonably good predictors of, total hit scores fired from both the supported and unsupported firing positions.

Group 2. Table 2 hit scores ranged from 3 to 19 ($M = 13.92$, $SD = 3.37$) while total hit scores ranged from 9 to 37 (M = 26.63, SD = 5.86). Following the same cross-validation procedures described earlier, the Group 1 regression equation was used to predict Group 2 total hit scores, and then the relative amount of variance accounted for in each group was compared. A significant linear relation, $Y' = -1.35 + 1.06(X_1[predicted])$, $SE = 3.40$, was found between actual and predicted (from Group 1) total hit scores for Group 2, $F(1, 88) = 176.23$. The resulting correlation ($r = .82$) was significant, and the associated Group 2 r^2 of .667 (adjusted $r^2 = .663$) did not differ significantly from the r^2 of .731 (adjusted $r^2 = .728$) found for Group 1 ($z = .83$), indicating that the Group 1 prediction equation accounted for a comparable amount of total hit score variance in the two groups. Thus, the Group 1 predictive model was found to be valid and, therefore, likely to maintain similar efficiency when used to predict the total hit scores of other shooter samples.

Pooled Groups

The results of the individual group analyses performed on Table 1 and 2 scores identified and confirmed the presence of a positive linear relation between Table 1 and total, and between Table 2 and total, hit scores. These relations can, in turn, be used to predict which shooters will fire the minimum qualification scores of 23 for Marksman, 30 for Sharpshooter, and 36 for Expert. To provide the best possible basis from which to make such predictions, and given the similar outcome of the separate group analyses, Group 1 and 2 Table 1 scores were pooled and Group 1 and 2 Table 2 scores were pooled. A separate pooled-group ($N = 180$) regression equation was then computed for each table.

Table 1 Prediction Model. For the pooled sample, Table 1 hit scores ranged from 3 to 20 ($M = 12.63$, $SD = 3.42$). Total hit scores ranged from 4 to 37 ($M = 26.72$, $SD = 5.73$) with 138 out of 180 shooters (77%) successfully qualifying with a first-attempt score of 23 hits or more. The correlation ($r = .83$) between Table 1 and total hit scores was significant, with the former accounting for over two thirds of the variance in the latter ($r^2 = .686$, adjusted $r^2 = 684$). Figure 1 shows the resulting scatterplot along with the significant best fit regression line, $F(1, 178) = 388.80$.

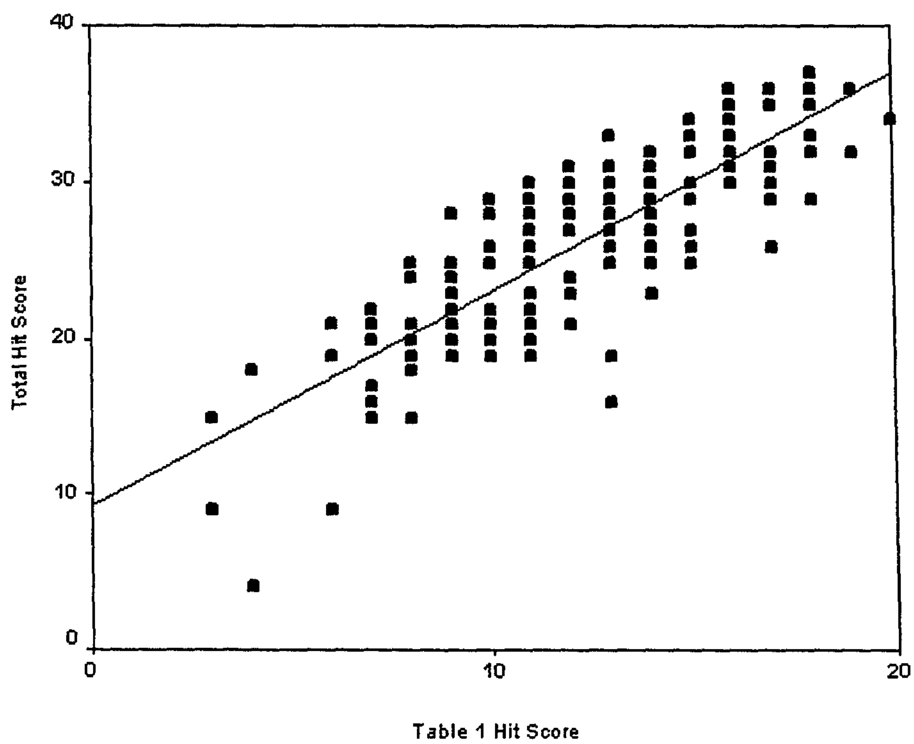

Figure 1. Relation between Table 1 and total hit scores for pooled data.

Based on the equation for this line, $Y' = 9.17 + 1.39(X_1)$, $SE = 3.27$, shooters with a Table 1 hit score (X_1) of 10, for example, will on the average be predicted to fire a minimum qualification score (Y') of 23. Similarly, a Table 1 score of 15 would be associated with the minimum Sharpshooter qualification score of 30. Assuming that the actual probability of firing the minimum predicted score at each qualification level will follow a normal distribution, with $M = 23$ and $SE_{\text{ind}}\ Y' = 3.40$ (Marksman), $M = 30$ and $SE_{\text{ind}}\ Y' = 3.44$ (Sharpshooter), and $M = 36$ and $SE_{\text{ind}}\ Y' = 3.48$ (Expert) (See Hays, 1963, p. 523.), the probability of an individual shooter firing a total hit score associated with each level was calculated for a selected range of Table 1 hit score values.

Table 1 below shows this range of shooter Table 1 scores along with their predicted mean total scores and associated probability of scoring from 23-29, 30-35, and 36-40, respectively, during first-attempt qualification firing. Using this table, a unit marksmanship trainer could predict that a shooter with a Table 1 score of 13 (column 1), for instance, will, on the average, fire a total score of 27 (column 2) and have an 90% chance of successful qualification at the Marksman level (column 3), a 20% chance of qualification at the Sharpshooter level (column 4), and less than a 10% chance of qualification at the Expert level (column 5). A shooter with a Table 1 score of 17 would be predicted to fire a total score of 33 and have greater than a 90% chance of qualifying Marksman, an 80% chance of qualifying Sharpshooter, a 20% chance of qualifying Expert, and so forth.

Table 1.

Table 1-Based Tool for Predicting the Probability of Shooter Qualification Ratings of Marksman (23-29), Sharpshooter (30-35), and Expert (36-40).

Actual Table 1 Hit Score	Predicted Mean Total Hit Score	Probability (%) of a Total Hit Score of...		
		23-29	30-35	36-40
7	19	10	--	--
8	20	20	--	--
9	21	30	--	--
10	23	50	--	--
11	24	60	--	--
12	26	80	10	--
13	27	90	20	--
14	28	--	30	--
15	30	--	50	--
16	31	--	60	10
17	33	--	80	20
18	34	--	90	30
19	35	--	--	40
20	37	--	--	60

Table 2 Prediction Model. For the pooled sample, Table 2 scores ranged from 0 to 20 (M = 14.08, SD = 3.48) while total hit score descriptives were identical to those reported for pooled data under the Table 1 Prediction Model section. The correlation (r = .84) between Table 2 and total hits was significant, with the former accounting for over two thirds of the variance in the latter (r^2 = .696, adjusted r^2 = .695). Figure 2 shows the resulting scatterplot along with the significant best fit regression line, $F(1, 178) = 408.30$.

Based on the equation for this line, $Y' = 7.34 + 1.38(X_1)$, SE = 3.17, shooters with a Table 2 hit score of 11, for example, will, on the average, fire a minimum qualification score of 23. Similarly, a Table 2 score of 16 would be associated with the minimum Sharpshooter qualification score of 30. Assuming that the actual probability of firing the minimum predicted score at each qualification level will follow a normal distribution, with M = 23 and $SE_{\text{ind}}\ Y'$ =

3.27 (Marksman), $M = 30$ and $SE_{ind}\ Y' = 3.31$ (Sharpshooter), and $M = 36$ and $SE_{ind}\ Y' = 3.34$ (Expert) (See Hays, 1963, p. 523), the probability of an individual shooter firing a total hit score associated with each level was calculated for a selected range of Table 2 hit score values.

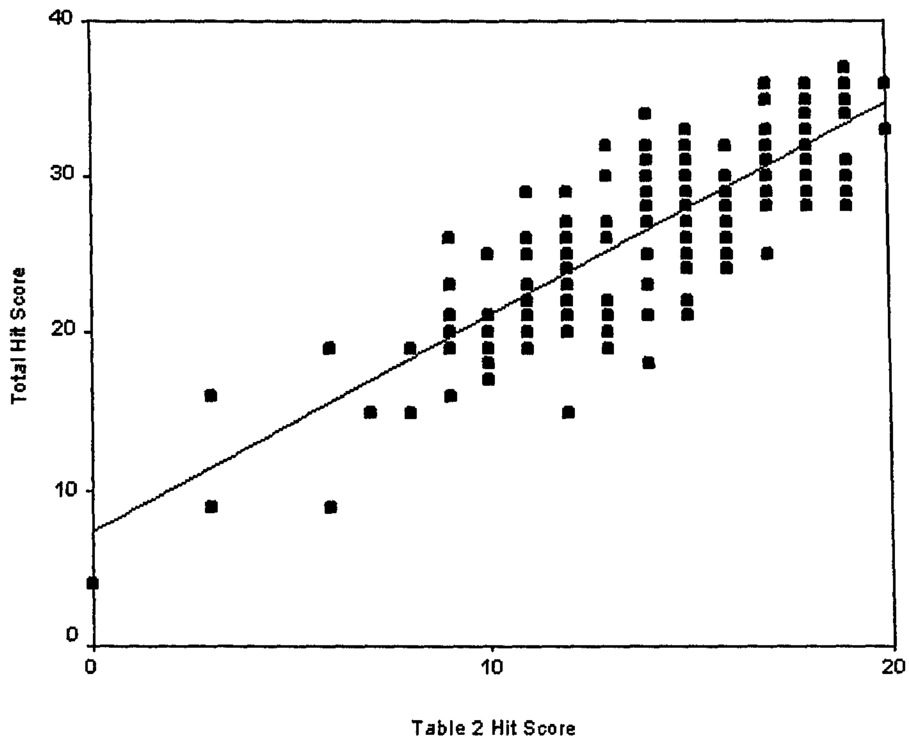

Figure 2. Relation between Table 2 and total hit scores for pooled data.

Table 2 below shows this range of shooter Table 2 scores along with their predicted mean total scores and associated probability of scoring from 23-29, 30-35, and 36-40 during first-attempt qualification firing. Using this table, a unit trainer could predict that a shooter with a Table 2 score of 14 (column 1), for instance, will on the average fire a total hit score of 27 (column 2) and have a 90% chance of qualifying Marksman (column 3), a 20% chance of qualifying Sharpshooter (column 4), and less than a 10% chance of qualifying Expert (column 5). A shooter with a Table 2 score of 19 would be predicted to fire a total score of 33 and have a greater than 90% chance of qualifying Marksman, an 80% chance of qualifying Sharpshooter, and a 20% chance of qualifying Expert, and so forth.

Overall, these findings indicate that (a) a positive linear relation exists between total table hit scores and individual table hit scores fired from either the Table 1 supported or Table 2 unsupported position, and (b) these relations are both consistent and of sufficient magnitude to support development of practicable tools, in the form of look-up tables, for predicting the probability of first-attempt success on the Army's standard qualification course at the Marksman, Sharpshooter, and Expert levels. Thus, rifle marksmanship proficiency, heretofore measured on the basis of 40 rounds, can be accurately predicted on the basis of only 20 rounds fired from either the supported or unsupported position.

Table 2.

Table 2-Based Tool for Predicting the Probability of Shooter Qualification Ratings of Marksman (23-29), Sharpshooter (30-35), and Expert (36-40).

Actual Table 2 Hit Score	Predicted Mean Total Hit Score	Probability (%) of a Total Hit Score of... 23-29	30-35	36-40
8	19	10	--	--
9	20	20	--	--
10	21	30	--	--
11	23	50	--	--
12	24	60	--	--
13	26	80	10	--
14	27	90	20	--
15	28	--	30	--
16	30	--	50	--
17	31	--	60	--
18	32	--	70	10
19	33	--	80	20
20	35	--	90	40

Applications

The resulting Table 1- and Table 2-based prediction tools developed from pooled data can serve as diagnostic instruments for helping Army marksmanship trainers make quick and accurate assessments of who should complete qualification firing (e.g., those shooters with at least a 50% chance of qualifying Marksman after firing 20 rounds) and who should not (e.g., those shooters with less than a 50% chance of qualifying at least Marksman after firing 20 rounds). These same tools can also be used to predict the success of practice qualification firing, provided the same scoring procedures and targets used during qualification are also used during practice. Thus, candidates in need of remedial training can be identified either before (i.e., during practice) or during qualification firing on the basis of 20 rather than 40 rounds fired, thereby stretching yearly ammunition allocations to ensure sufficient availability of rounds for practice/remediation, qualification, and qualification refiring (as needed for shooters failing to qualifying on their first attempt).

Each of these tools also provides an empirically derived set of marksmanship performance probabilities for use in setting new practice and qualification standards for both supported and unsupported positions fired on Tables 1 and 2, respectively. Such standards, in the form of cutoff scores, would be needed should the Army authorize the option to use 20 rounds, in lieu of 40, for purposes of satisfying yearly rifle marksmanship requirements. The Army might determine, for instance, that, for shooters to earn a practice or qualification rating of Marksman (i.e., 23-29), they must fire a 20-round score of 12 from the supported firing position or 13 from the unsupported firing position. Both of which would be associated with a predicted 80% chance of successful 40-round practice or qualification. Analogous standards could also be set for Sharpshooter and, to a lesser extent, Expert for each firing position.

Although hit scores from either the supported or unsupported firing position (either Table 1 or 2) could potentially be used to predict practice and qualification proficiency, use of supported position scores from Table 1 would be recommended given that unsupported position predictions from Table 2 are contingent upon the prior firing of 20 supported position rounds. Firing from the supported position, therefore, may have affected the value of unsupported position scores and their related predictive accuracy. Thus, additional field testing, where the unsupported position is fired before the supported position, is needed to assess the predictive capabilities of the former uncontaminated by potential firing order transfer or carryover effects from the latter.

Indiscriminate use of the supported firing position prediction tool shown in Table 1 is cautioned, however, for a couple of reasons. First, supported position predictions may not generalize to other shooter samples or other qualification ranges. The number of hits scored by the current sample of novice shooters (i.e., Infantry OSUT trainees), for example, may not be representative of the number of hits scored by more experienced shooters. In addition, the difficulty level of the Fort Benning BRM qualification range used in this research may not be comparable to that of ranges located elsewhere. Thus, marksmanship trainers may need to develop their own prediction tools to account for shooter experience and range difficulty. Windows-Based software designed specifically for prediction tool development (Hagman, 2000, September-December; Hagman, 2004) can be obtained via e-mail from the author at jhagman@boisestate.edu. Once the supported (Table 1) and total hit score values are entered, the software will calculate the desired predictions and print them out in tabular format for quick and easy use.

Finally, because marksmanship can be evaluated on the sole basis of supported firing position performance, it might be tempting to restrict training to the supported position too, thereby enhancing the efficiency of both marksmanship training and evaluation. The correlation, however, between pooled data supported and unsupported hit scores, although later found to be significant, was relatively low ($r = .38$), suggesting that the amount of skill overlap between the two firing positions is far from complete. Thus, both positions need to be trained but only the supported position needs to be evaluated. Further field testing is required to determine if the same could be said of the unsupported position.

Until such field testing is done, the present research provides Army trainers with an easy-to-use tool for (a) predicting/evaluating live-fire rifle marksmanship performance based on 50% fewer rounds than currently fired on the Army's standard qualification course during practice and actual qualification, (b) quickly identifying shooters in need of remedial training both before and during qualification firing, and (c) supporting the option of using fewer rounds for yearly practice and qualification firing when evaluation time and ammunition are in short supply.

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